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# System Dynamics Model on Urban Growth with an Application to Okayama City

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Synopsis

A system dynamics model to forecast future movements of a city was studied. The model consists of three sections of population sector, industry sector, land use sector and some divisions of labor, income employment, housing land which connect each sections. Economic growth rate, public investment program, housing land supply program were incorporated in the model as political variables.

The model was applied to Okayama city for thirty years from 1975 to 2005. The results of the simulation are summarized as follows:

1) The drift of peoples into Okayama city will advance in the future.
2) Tertiary industries will be given much weight as compared with secondary industries.
3) Because of the drift of peoples, housing problems will be serious in the future.

## 1. Introduction

Now, urban problems originate to the cycle of drift of population and growth of cities. The concentration of urban facilities and peoples towards cities increase the production ability and employment

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oppotunity. They increase attractiveness of cities through improvement of facilities of education, culture, residence and traffic. Then further concentration of urban facilities and peoples are stimulated.

In order to settle urban problems, it is necessary to make clear the structure of urban systems and its causal relation and to make programs on a long-range forecast. In urban systems, causal relation loops are ordinarily very complicated and act non-linearly in dynamical correlation. Also it lacks data essentially, so that the efficiency of forecast models based on statistical data processing is limited. On the other hand in system dynamics [1],[2], system is not regarded as a black box, but its structure and dynamical action are understood in detail. In this sense, system dynamics can be thought as a structure-depended way not a parameter-depended one. It will be the most suitable tool for model construction of social systems lacked of data essentially, and contribute for the solution of urban problems.

In this paper, an urban growth model is constructed by use of system dynamics. It is applied to Okayama city and movements of urban growth are observed. In Okayama prefecture, concentration of industries and population towards cities in southern part of the prefecture is in progress, and the central and nothern part of the prefecture is stagnant. Going with the current, cities in southern part will be overpopulated, and the living environment will be surely grow worse. On the other hand, the nothern part will be still more depopulated and the investment to living and industry bases will become unefficient.

To avoid such a situation, regional development programs should be formulated on the basis of a proper forecast of the region.

## 2. Structure of the Model

### 2.1 General

The model described in this paper forecast future conditions such as population, indutry and land use in Okayama city. It is assumed that public investment programs to living and industry bases, economic growth rate and housing land supply program are given exogenously. The model generally consists of three sections of population sector, industry sector and land use sector. Each section is connected by some divisions namely income, labor, employment and housing land. The outline of the model is shown in Fig.1.

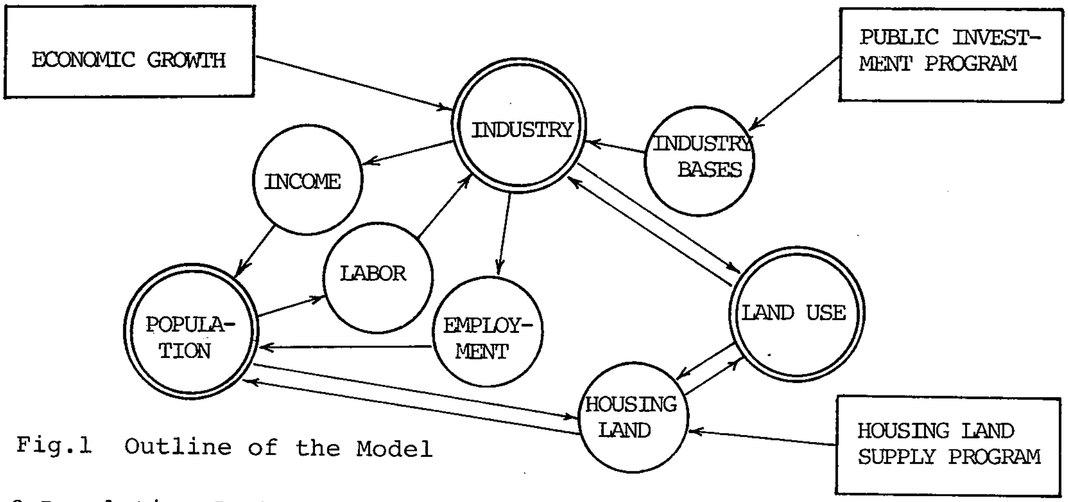


Fig.1 Outline of the Model

## 2.2 Population Sector

In this sector two areas are considered, namely Okayama city and Okayama prefectural area. The latter consists of the whole area of Okayama prefecture except Okayama city. The population of each area is decided by birth,death,moving-in and moving-out. With respect to migration, attractiveness-for-migration multiplier by J.W.Forrester [3] is used. The flow diagram of population sector is shown in Fig.2.

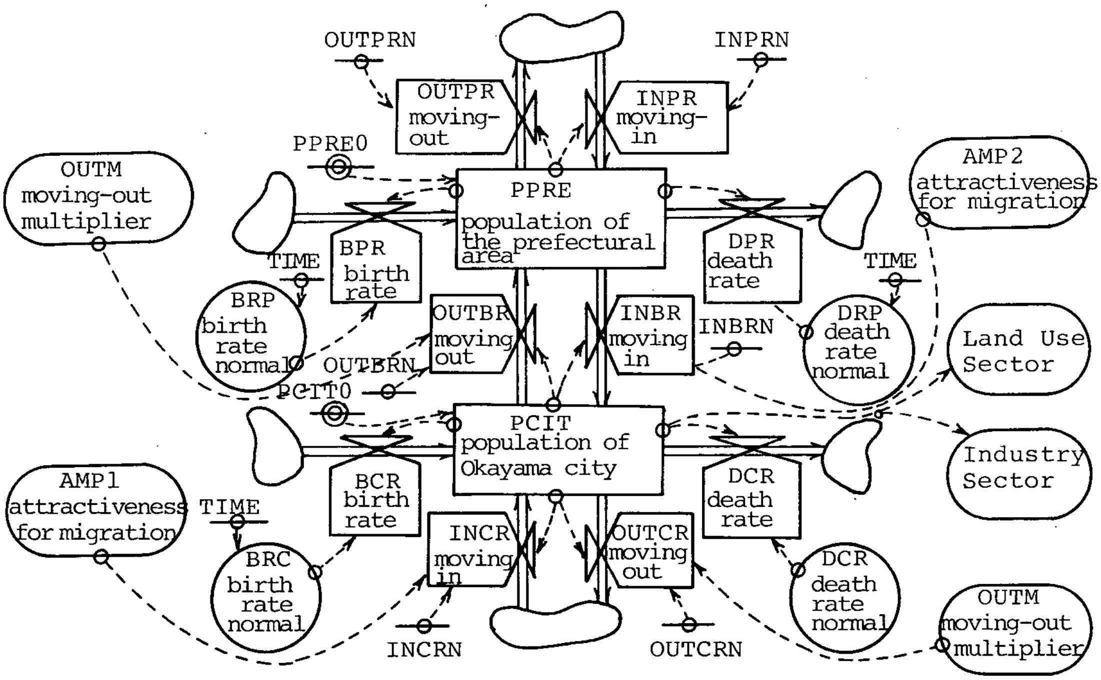


Fig.2 Flow Diagram of Population Sector

```
NOTE   POPULATION OF THE PREFECTURAL AREA
L      PPRE.K=PPRE.J+(DT)(BPR.JK-DPR.JK+INPR.JK
X               -OUTPR.JK+OUTBR.JK-INBR.JK)
N      PPRE=PPRE0
R      BPR.KL=PPRE.K*BPR.K
R      DPR.KL=PPRE.K*DRP.K
R      INPR.KL=INPRN*PPRE.K
R      OUTPR.KL=OUTPRN*PPRE.K
A      BXP.K=273.4-0.131*TIME.K
A      DXP.K=135.9-0.065*TIME.K
A      BRP.K=BXP.K*E
A      DRP.K=DXP.K*E
C      E=1.0E-2
```

PPRE : population of the prefectural area (men)
BPR, BRP : birth rate(men/year), birth rate normal(fraction/year)
DPR, DRP : death rate(men/year), death rate normal(fraction/year)
INPR, INPRN : moving-in rate (men/year), normal (fraction/year)
OUTPR, OUTPRN : moving-out rate (men/year), normal (fraction/year)
BXP : birth rate regression (%)
DXP : death rate regression (%)
TIME : year (A.D.)

Population level of the prefectural area PPRE is calculated by that of the previous time point and differences of each rate of birth BPR, death DPR, moving-in INPR and moving-out OUTPR. Birth rate and death rate normal BRP, DRP were decided by regressions based on the past statistical data [4],[5],[6],[7]. Moving-in and Moving-out rate normal INPRN, OUTPRN were also decided by the statistical data.

```
NOTE   POPULATION OF OKAYAMA CITY
L      PCIT.K=PCIT.J+(DT)(BCR.JK-DCR.JK+INBR.JK-OUTBR.JK
X                     +INCR.JK-OUTCR.JK)
N      PCIT=PCIT0
R      BCR.KL=PCIT.K*BRC.K
R      DCR.KL=PCIT.K*DRC.K
R      INBR.KL=INBRN*PCIT.K*AMP2.K
R      INCR.KL=INCRN*PCIT.K*AMP1.K
R      OUTBR.KL=OUTBRN*OUTM.K*PCIT.K
R      OUTCR.KL=OUTCRN*OUTM.K*PCIT.K
A      BXC.K=274-0.131*TIME.K
A      DXC.K=99-0.047*TIME.K
A      BRC.K=BXC.K*E
A      DRC.K=DXC.K*E
```

PCIT,PCIT0 : population of Okayama city (men), initial (men)
INBR, INBRN : moving-in rate from the prefectural area (men/year), normal (fraction/year)
OUTBR, OUTBRN : moving-out rate to the prefectural area (men/year, normal (fraction/year)
INCR, INCRN : moving-in rate from out of the prefecture (men/year), normal (fraction/year)
OUTCR, OUTCRN : moving-out rate to out of the prefecture (men/year), normal (fraction/year)
AMP1 : attractiveness multiplier perceived for migration from out of the prefecture (dimensionless)
AMP2 : attractiveness multiplier perceived for migration from the prefectural area (dimensionless)

This is almost the same as that of the prefectural area, except consideration of migration to and from the prefectural area OUTBR, INBR and to and from out of the prefecture OUTCR,INCR. Attractiveness-for-migration multiplier perceived AMP1, AMP2 influence upon moving-in rate INBR, INCR.

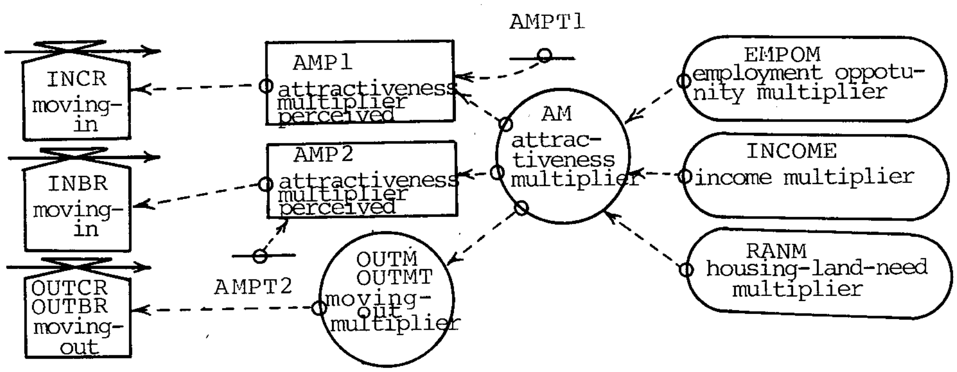


Fig.3 Flow Diagram of Attractiveness-For-Migration Multiplier

```
NOTE   ATTRACTIVENESS-FOR-MIGRATION MULTIPLIER PERCEIVED
NOTE   FROM OUT OF THE PREFECTURE
L      AMP1.K=AMP1.J+(DT/AMPT1)(AM.J-AMP1.J)
N      AMP1=1
C      AMPT1=20
NOTE   FROM THE PREFECTURAL AREA
L      AMP2.K=AMP2.J+(DT/AMPT2)(AM.J-AMP2.J)
N      AMP2=1
C      AMPT2=10
NOTE   MOVING-OUT MULTIPLIER
A      OUTM.K=TABLE(OUTMT,1.44*LOGN(AM.K),-3,3,1)
T      OUTMT=8/4/2/1/0.5/0.25/0.125
NOTE   AM.K=EMPOM.K*RANM.K*INCOMM.K
```

AM : attractiveness-for-migration multiplier (dimensionless)
EMPOM : employment-oppotunity multiplier (dimensionless)
INCOMM : income multiplier (dimensionless)
RANM : housing-land-need multiplier (dimensionless)
AMPT1 : perception time for AMP1 (=20 years)
AMPT2 : perception time for AMP2 (=10 years)
OUTM : moving-out multiplier (dimensionless)
OUTMT : moving-out multiplier table

Attractiveness-for-migration multiplier AM is given by the product of employment-oppotunity multiplier EMPOM, income multiplier INCOMM and housing-land-need multiplier RANM. Attractiveness multiplier perceived AMP1 and AMP2 are exponential time-lag of first order, assuming that time constants are 20 years and 10 years respectively.

Moving-out multiplier OUTM is given by moving-out table OUTMT, in which OUTM is supposed to be inversely proportional to AM and is given weight by logarithmic transformation. Moving-out table is shown in Fig.4.

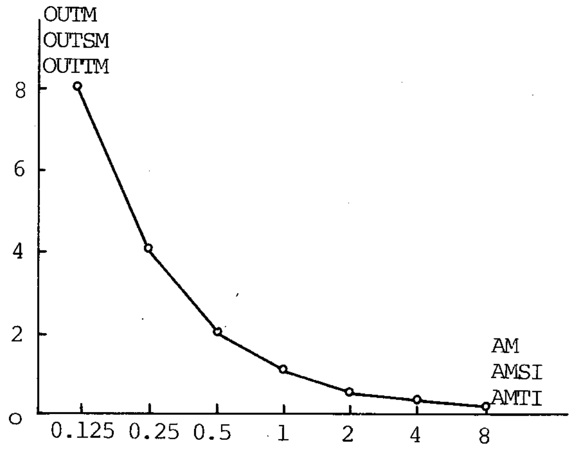


Fig.4 Moving-Out Table

## 2.2 Industry Sector

Concerning to secondary and tertialy industries, the flow of establishment and net product are considered. As the rate which decide the level of the number of establishment, advance and retreat in case of secondary industries, growth and extinction in case of tertiary industries are introduced. Attractiveness multiplier similar to population sector is also used in this sector. The normal value of each rate are decided based on statistical data. The level of net product is calculated by production rate, which is controlled by economic growth rate. The flow diagram of industry sector is shown in Fig.5.

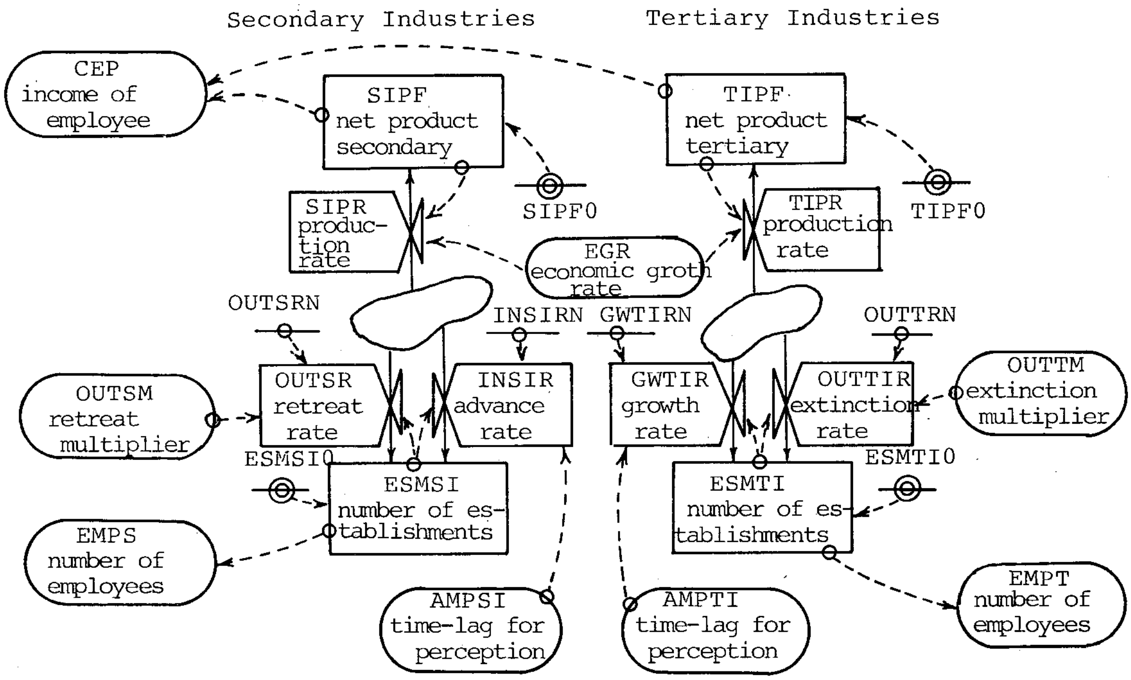


Fig.5 Flow Diagram of Industry Sector

```
NOTE   SECONDARY INDUSTRIES
L      ESMSI.K=ESMSI.J+(DT)(INSIR.JK-OUTSR.JK)
N      ESMSI=ESMSI0
R      INSIR.KL=INSIRN*AMPSI.K*ESMSI.K
R      OUTSR.KL=OUTSRN*ESMSI.K*OUTSM.K
NOTE   TERTIARY INDUSTRIES
L      ESMTI.K=ESMTI.J+(DT)(GWTIR.JK-OUTTR.JK)
N      ESMTI=ESMTI0
R      GWTIR.KL=GWTIRN*AMPTI.K*ESMTI.K
R      OUTTR.KL=OUTTRN*ESMTI.K*OUTTM.K
```

ESMSI : number of establishments of secondary industries (places)
ESMTI : number of establishments of tertiary industries (places)
INSIR, INSIRN : advance rate for secondary industries (places/ year), normal (fraction/year)
OUTSR, OUTSRN : retreat rate for secondary industries (places/ year), normal (fraction/year)
GWTIR, GWTIRN : growth rate for tertiary industries (places/year) , normal (fraction/year)
OUTTR, OUTTRN : extinction rate for tertialy industries (places), normal (fraction/year)
AMPSI : attractiveness-for-advance multiplier perceived (dimensionless)
AMPTI : attractiveness-for-growth multiplier perceived (dimensionless)

```
NOTE   PRODUCT OF SECONDARY INDUSTRIES
L      SIPF.K=SIPF.J+(DT)(SIPR.JK-0)
N      SIPF=SIPF0
R      SIPR.KL=SIPF.K*EGR.K
NOTE   PRODUCT OF TERTIARY INDUSTRIES
L      TIPF.K =TIPF.J+(DT)(TIPR.JK+0)
N      TIPF=TIPF0
R      TIPR.KL=TIPF.K*EGR.K
```

SIPF : net product of secondary industries (productive units)
TIPF : net product of tertiary industries (productive units)
SIPR : production rate of secondary industries (productive units /year)
TIPR : production rate of tertiary industries (productive units/ year)
EGR : economic growth rate (fraction)

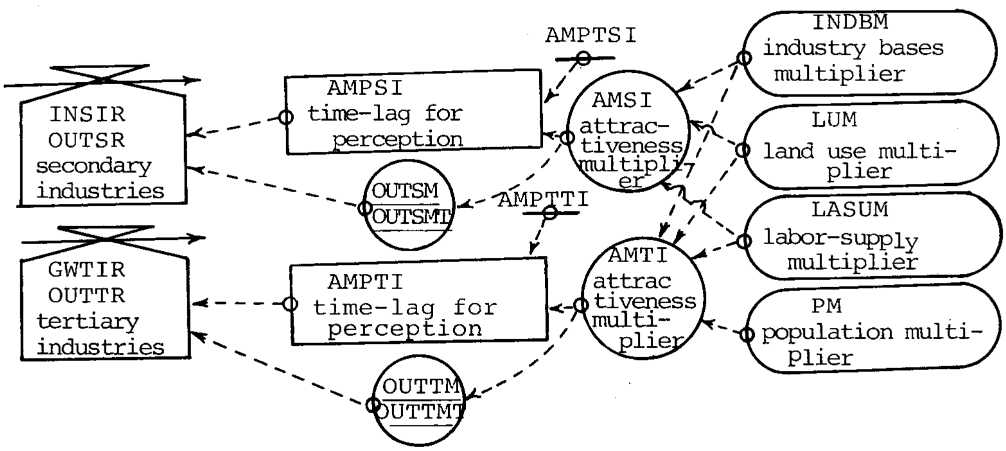


Fig.6 Attractiveness Multiplier of Industries

```
NOTE   ATTRACTIVENESS-FOR-ADVANCE MULTIPLIER PERCEIVED
NOTE   FOR SECONDARY INDUSTRIES
L      AMPSI.K=AMPSI.J+(DT/AMPTSI)(AMSI.J-AMPSI.J)
N      AMPSI=1
C      AMPTSI=5
NOTE   ATTRACTIVENESS-FOR-GROWTH MULTIPLIER PERCEIVED
NOTE   FOR TERTIARY INDUSTRIES
L      AMPTI.K=AMPTI.J+(DT/AMPTTI)(AMTI.J-AMPTI.J)
N      AMPTI=L
C      AMPTTI=5
NOTE   ATTRACTIVENESS-FOR-ADVANCE MULTIPLIER
A      AMSI.K=LASUM.K*INDBM.K*LUM.K
A      OUTSM.K=TABLE(OUTSM,1.44*LOGN(AMSI.K),-3,3,1)
T      OUTSMT=8/4/2/1/0.5/0.25/0.125
NOTE   ATTRACTIVENESS-FOR-GROWTH MULTIPLIER
A      AMTI.K=LASUM.K*PM.K*INDBM.K*LUM.K
A      OUTTM.K=TABLE(OUTTMT,1.44*LOGN(AMTI.K),-3,3,1)
T      OUTTMT=8/4/2/1/0.5/0.25/0.125
```

AMPTSI : perception time for AMSI (=5 years)
AMPTTI : perception time for AMTI (=5 years)
OUTSM : retreat multiplier for secondary industries
OUTTM : extinction multiplier for tertiary industries
AMSI : attractiveness-for-advance multiplier for secondary industries
AMTI : attractiveness-for-growth multiplier for tertially industries
INDBM : industry-bases multiplier
LUM : land-use multiplier
LASUM : labor-supply multiplier
PM : population multiplier

Time lag for perception for attractiveness multiplier is assumed to be exponential of first order with perception time 5 years. Retreat and extinction multiplier OUTSM, OUTTM are supposed to be inversely proportional to attractiveness multiplier and is given weight also by logarithmic transformation.

Attractiveness-for-advance multiplier for secondary industries AMSI is given by the product of industry-bases multiplier INDBM, land-use multiplier LUM and labor-supply multiplier LASUM. Tertiary industries such as service, transportation and retail fairly depend on population, so that attractiveness-for-growth multiplier for tertiary industries AMTI is given by the product of INDBM, LUM, LASUM and population multiplier PM.

## 2.3 Land Use Sector

In this sector it is considered how land use in Okayama city variate according to increase of population and development of industries.

Housing-land is assumed to be supplied constantly by private enterprises and politicaly by public institutions. The area of industries is calculated by multiplying average area per establishment by number of establishments. The flow diagram of land use sector is shown in Fig.7.

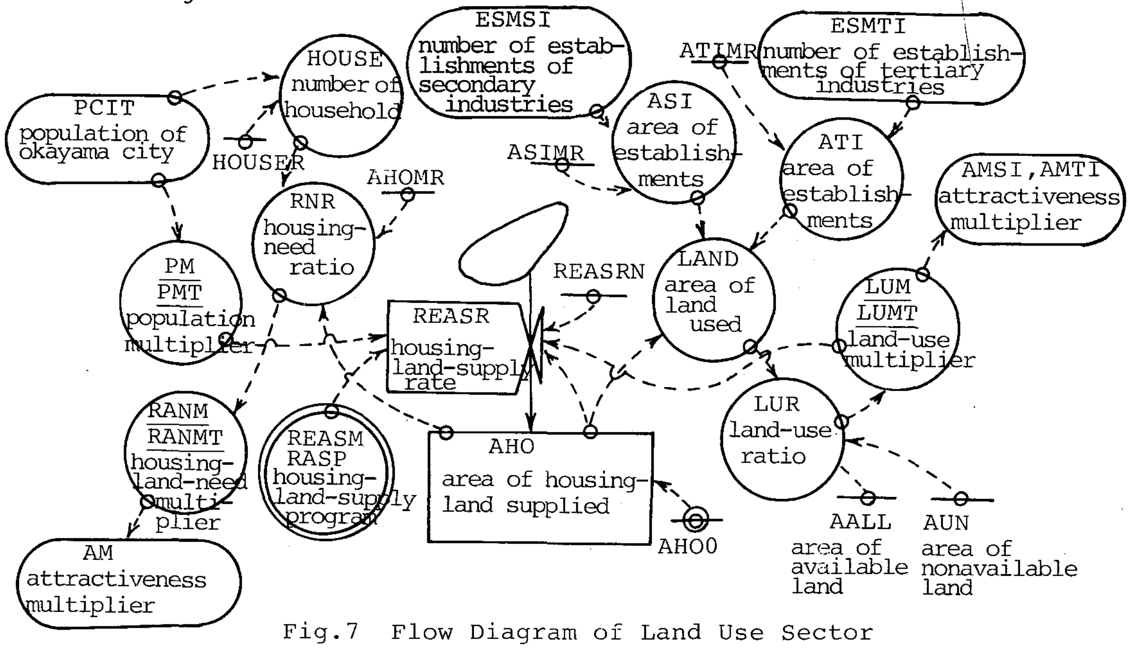


Fig.7 Flow Diagram of Land Use Sector

```
NOTE    HOUSING-LAND
A       HOUSE.K=PCIT.K/HOUSER
L       AHO.K=AHO.J+(DT)(REASR.JK+0)
N       AHO=AHO0
R       REASR.KL=AHO.K*(REASRN+REASM.K)*LUM.K*PM.K
NOTE    HOUSING-LAND NEED RATIO
A       DWELL.K=HOUSE.K*AHOMR
A       RNR.K=AHO.K/DWELL.K-1
A       RANM.K=TABLE(RANMT,RNR.K,-1,1,0.4)
T       RANMT=0/0.2/0.6/1.4/1.8/2
```

HOUSE : number of households
HOUSER : family size (3.2 men/household)
PCIT : population of okayama city (men)
AHO : area of housing-land supplied ($Km^2$)
RNR : housing-land-need ratio (fraction)
RANM : housing-land-need multiplier
RANMT : housing-land-need multiplier table
REASM : housing-land-supply program (fraction/year)
REASR : housing-land-supply rate ($Km^2$/year)
DWELL : area of housing-land demanded ($Km^2$)

Housing-land-need ratio RNR is the ratio of the difference between housing-land supplied AHO and housing-land demanded DWELL to DWELL. RNR influences on attractiveness multiplier of population sector AM. AM is magnified if housing-land-supply is large. This situation is shown as housing-land-need multiplier table RANMT in Fig.8. Housing-land-supply program REASM is a public supply and is assumed to be an exogenous variable.

```
NOTE  LAND-USE OF SECONDARY INDUSTRIES
A     ASI.K=ASIMR*ESMSI.K
NOTE  LAND-USE OF TERTIALY INDUSTRIES
A     ATI.K=ATIMR*ESMTI.K
```

ASI : total area of secondary industries establishments ($Km^2$)
ASIMR : area per establishment ($Km^2$)
ATI : total area of tertiary industries establishments ($Km^2$)
ATIMR : area per establishment ($Km^2$)
ESMSI : number of secondary industries establishments
ESMTI : number of tertiary industries establishments

```
NOTE  REMAINING AVAILABLE LAND
A     LAND.K=AHO.K+ASI.K+ATI.K
S     AO.K=AALL-AUN-LAND.K
NOTE  LAND-USE RATE
A     LUR.K=LAND.K/(AALL-AUN)
NOTE  LAND-USE MULTIPLIER
A     LUM.K=TABLE(LUMT,LUR.K,0,1,0.2)
T     LUMT=1/0.8/0.6/0.4/0.2/0
```

LAND : area of land used ($Km^2$)
AO : area of remaining available land ($Km^2$)
AUN : area of non-available land ($Km^2$)
AALL : area of land ($Km^2$)
LUR : land use ratio (fraction)
LUM : land use multiplier
LUMT : land use multiplier table

LUR is the ratio of the area of land used by industries and households to the area of available land. If LUR is close to 1, then attractiveness multiplier of population sector and industry sector are reduced. This is because land price rises and industrial location is got into difficulty if available land is decreased. This situation is shown as land-use multiplier table LUMT shown in Fig.9.

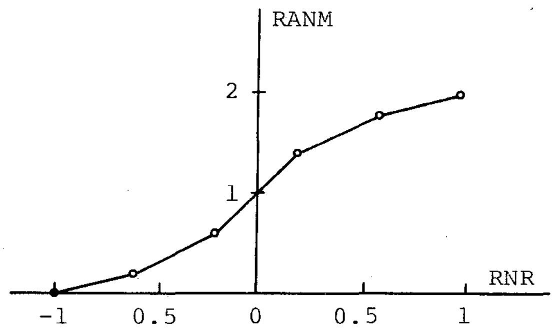

Fig.8 Housing-Land-Need Multiplier Table

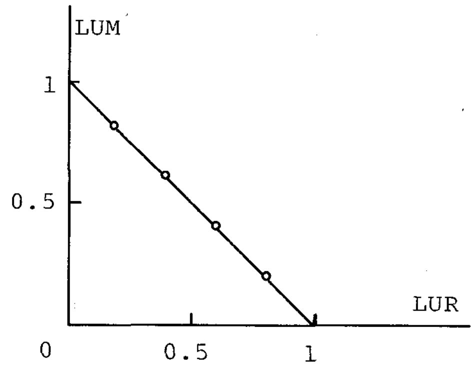

Fig.9 Land-Use Multiplier Table

## 2.4 Other Divisions

The flow diagram of other divisions is shown in Fig.10.

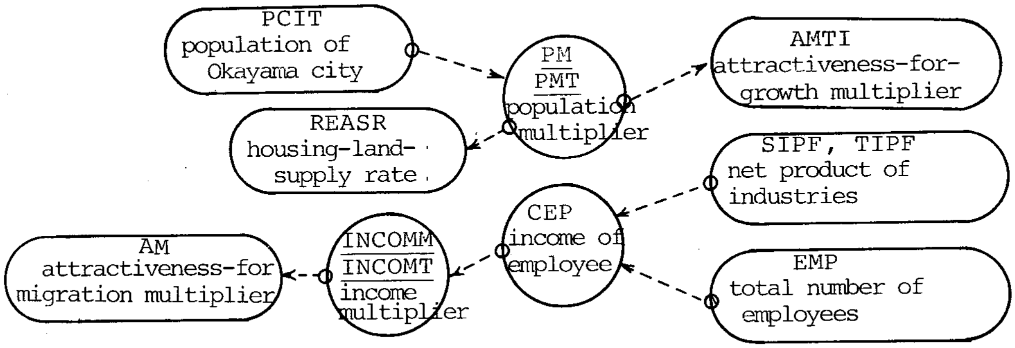


Fig.10 Flow Diagram of Other Divisions

```
NOTE   POPULATION MULTIPLIER
A      PI.K=PCIT.K/PCIT0
A      PM.K=TABLE(PMT,PI.K,0,3,1)
T      PMT=0/1/1.6/2
```

PI : population increase ratio (fraction/year)
PM : population multiplier
PMT : population multiplier table

Tertiary industries fairly depend on population, so that they increase attractiveness with population increase ratio PI. Also housing-land-supply by private enterprise is supposed to be influenced by population multiplier. Population multiplier table PMT is shown in Fig.11.

```
NOTE   INCOME OF EMPLOYEE
A      CEP.K=(SIPF.K+TIPF.K)*0.6/EMP.K
A      CEPI.K=CEP.K/CEP0
NOTE   INCOME MULTIPLIER
A      INCOMM.K=TABLE(INCOMT,CEPI.K,0,5,1)
T      INCOMT=0/1/3/5/6/6.5
```

CEP : income of employee per person (yen)
CEPI : income increase ratio (fraction/person)
INCOMM : income multiplier
INCOMT : income multiplier table

Income of employee per person CEP is calculated by multiplying distribution rate 0.6 to net product of secondary and tertiary industries SIPF, TIPF and deviding by number of employees. The increase of income increase ratio CEPI rises attractiveness of population sector. This condition is shown in Fig.12 as income multiplier table INCOMT.

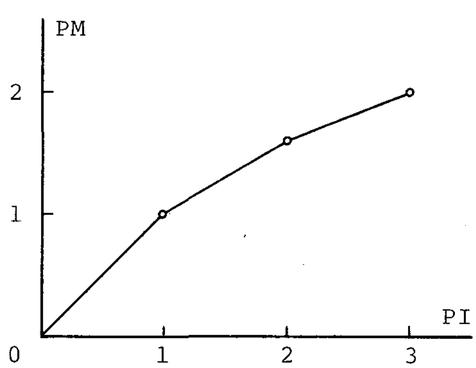


Fig.11. Population Multiplier Table

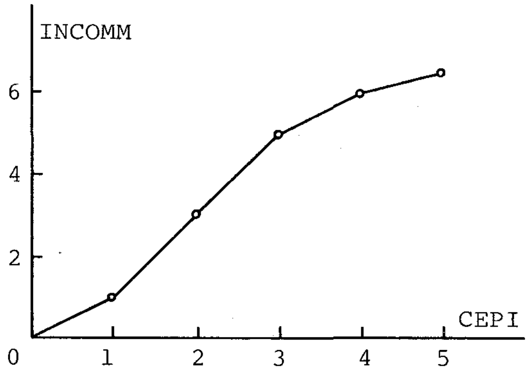


Fig.12 Income Multiplier Table

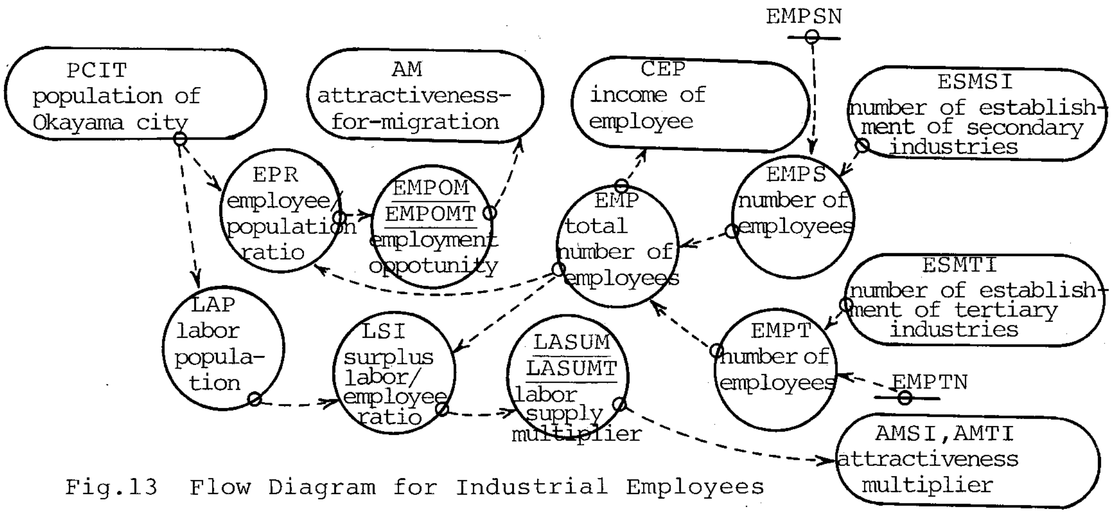


Fig.13 Flow Diagram for Industrial Employees

```
NOTE   EMPLOYEES OF SECONDARY INDUSTRIES
A      EMPS.K=EMPSN*ESMSI.K
NOTE   EMPLOYEES OF TERTIARY INDUSTRIES
A      EMPT.K=EMPYN*ESMTI.K
NOTE   EMPLOYEES OF SECONDARY AND TERTIARY INDUSTRIES
A      EMP.K=EMPS.K+EMPT.K
```

EMPS : number of employees of secondary industries (men)
EMPSN : average number of employees per establishment (men)
EMPT : number of employees of tertiary industries (men)
EMPTN : average number of employees per establishment (men)
EMP : total number of industrial employees (men)

Number of employees of secondary industries EMPS and tertiary industries EMPT are calculated by multiplying average number of employees per establishment EMPSN and EMPTN to number of establishment. Total number of industrial employees is the sum of both numbers.

```
NOTE   EMPLOYEES/POPULATION RATIO
A      EPR.K=EMP.K/PCIT.K
NOTE   EMPLOYMENT-OPPOTUNITY MULTIPLIER
A      EMPOM.K=TABLE(EMPOMT,EPR.K,0.1,1.9,0.2)
T      EMPOMT=3/1.4/0.9/0.65/0.5/0.4/0.35/0.3/0.25/0.2
```

EPR : number of employees / population ratio (fraction)
EMPOM : employment-oppotunity multiplier
EMPOMT : employment oppotunity multiplier table

Employment oppotunity multiplier EMPOM is supposed to be high when number of employees/population ratio EPR is low. It influence upon attractiveness multiplier through employment oppotunity multiplier table EMPOMT. EMPOMT is shown in Fig.14.

```
NOTE   LABOR-SUPPLY MULTIPLIER
A      LSI.K=LAP.K/EMP.K-1
A      LASUM.K=TABLE(LASUMT,LSI.K,-1,1,0.4)
NOTE   LABOR POPULATION
A      LAP.K=PCIT.K*0.5
```

LAP : labor population (men)
LSI : surplus labor/employees ratio (fraction)
LASUM : labor-supply multiplier
LASUMT : labor-supply multiplier table

Labor population which is defined as the population over fifteen years old is assumed to be half of the population. If labor population is greater than the number of employees namely if LSI is positive, attractiveness for industries increases. This situation is shown in Fig.15 as labor supply multiplier table LASUMT.

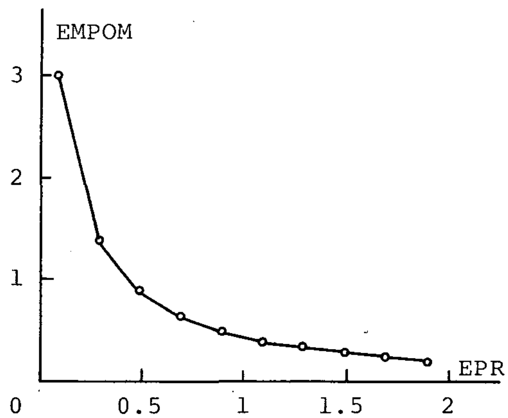


Fig.14 Employment-Oppotunity Multiplier Table

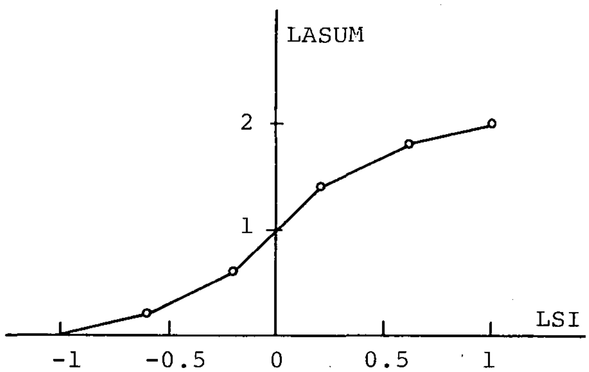


Fig.15 Labor-Supply Multiplier Table

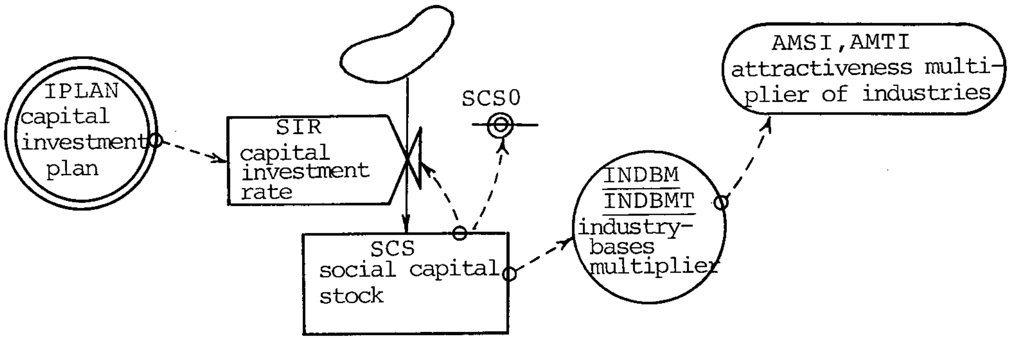


Fig.16 Flow Diagram for Social Capital Investment And Industry Bases Multiplier

```
NOTE   SOCIAL CAPITAL INVESTMENT
L      SCS.K=SCS.J+(DT)(SIR.JK+0)
N      SCS=SCS0
R      SIR.KL=SCS.K*IPLAN.K
NOTE   INDUSTRY-BASES MULTIPLIER
A      INDBM.K=TABLE(INDBMT,SCSI.K,0,4,1)
T      INDBMT=0/1/1.2/1.6/2.4
A      SCSI.K=SCS.K/SCS0
```

SCS : social capital stock (yen)
SIR : capital investment rate (yen/year)
IPLAN : capital investment program (fraction/year)
SCSI : increase ratio of social capital stock (fraction)
INDBM : industry-bases multiplier
INDBMT : industry-bases multiplier table

Social capital stock is represented by road investment, which is calculated by multiplying unit cost of construction to area of roads.

Social capital stock SCS is decided by capital investment rate SIR and is controlled by investment program IPLAN. IPLAN is a exogenous variable. The increase of increase of social capital stock SCSI rises attractiveness for industries. This situation is shown in Fig.17 as industry-bases multiplier table INDBMT.

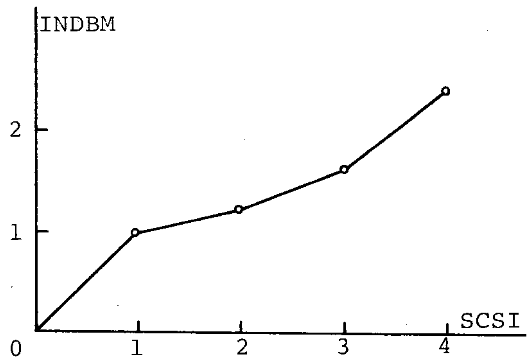


Fig.17 Industry-Bases Multiplier Table

Total flow diagram of the model is shown in Fig.18.

## 2.5 Parameters

The parameters used in the model were decided as follows based on statistical data.

```
NOTE   POPULATION SECTOR
C      PPRE0=1295590
C      INPRN=0.021
C      OUTPRN=0.024
C      PCIT0=518715
C      INBRN=0.019
C      OUTBRN=0.018
C      INCRN=0.035
C      OUTCRN=0.034
NOTE   INDUSTRY SECTOR
C      ESMSI0=4491
C      INSIRN=0.02
C      OUTSRN=0.002
C      ESMTI0=20452
C      GWTIRN=0.04
C      OUTTRN=0.004
C      SIPF0=1991E8
C      TIPF0=3232E8
NOTE   LAND USE SECTOR
C      HOUSER=3.2
C      AHO0=13.43
C      REASRN=0.01
C      AHOMR=0.82E-4
C      ASIMR=0.83E-3
C      ATIMR=0.95E-4
C      AALL=510.46
C      AUN=230.31
NOTE   OTHER DIVISIONS
C      EMPSN=15
C      EMPTN=7.5
C      CEP0=1.419E6
C      SCS0=6009E8
NOTE SIMULATION CONTROL VARIABLES
C      DT=1
C      TIME=1975
C      LENGTH=2005
```

## 3. Simulation Results

The simulation was executed for thirty years from 1975 to 2005. The policy variables were suppoesd as follows:

Social Capital Investment Program IP = 0.02 (fraction/year)

Economic Growth Rate GR = 0.06 (fraction/year)

Housing-Land-Supply Program by Public Institution RASP = 0.005 (fraction/year)

The main variables forcasted are as follows.

| year | 1975 | 1985 | 1995 | 2005 | 2005/1975 |
|---|---|---|---|---|---|
| MOVEMENTS OF POPULATION | | | | | |
| population of Okayama prefecture ($\times 10^4$ men) | 181.4 | 191.9 | 204.4 | 223.2 | 1.23 |
| population of the prefectural area ($\times 10^4$ men) | 129.6 | 134.0 | 136.0 | 132.7 | 1.02 |
| population of Okayama city ($\times 10^4$ men) | 51.87 | 57.86 | 68.38 | 90.45 | 1.74 |
| population density (men/$Km^2$) | 1016 | 1133 | 1340 | 1772 | 1.74 |
| number of employees ($\times 10^4$ men) | 18.16 | 20.31 | 25.59 | 37.38 | 2.06 |
| MOVEMENTS OF INDUSTRIES | | | | | |
| number of establishments of secondary industries | 4491 | 5323 | 5993 | 6649 | 1.48 |
| number of establishments of tertiary industries | 20450 | 28810 | 37420 | 49180 | 2.40 |
| net product of secondary industries ($\times 10^8$ yen) | 1991 | 3566 | 6385 | 11440 | 5.75 |
| net product of tertiary industries ($\times 10^8$ yen) | 3232 | 5788 | 10370 | 18560 | 5.74 |
| income per employee ($\times 10^4$ yen) | 172.6 | 276.3 | 392.8 | 481.5 | 2.79 |
| MOVEMENTS OF LAND USE | | | | | |
| housing-land supplied ($Km^2$) | 13.43 | 15.42 | 17.67 | 20.20 | 1.50 |
| area used by secondary industries ($Km^2$) | 3.73 | 4.42 | 4.97 | 5.52 | 1.48 |
| area used by tertiary industries ($Km^2$) | 1.94 | 2.74 | 3.56 | 4.67 | 2.41 |
| area used by housholds and industries ($Km^2$) | 19.10 | 22.57 | 26.19 | 30.39 | 1.59 |
| lack of housing-land-supply ($Km^2$) | 0.91 | 0.46 | 0.91 | 4.03 | 4.42 |

Table.1 Movements of Population, Industry And Land Use

Simulation results are summed up as follows.

Population Sector:

The population of Okayama city in 2005 will be 904,500 men that is 1.74 times as many as that in 1975. As from 1995, the prefectural population will decrease. This is because the drift of peoples of central and nothern part of the prefecture into southern cities. Attractiveness-for-migration multiplier increases to 104 in 1985, 132 in 1995 and 132 in 2005, as is 100 in 1975. The movements of population are shown in Fig.19.

Industry Sector:

Tertiary industries will be remarkably grow in Okayama city. The number of establishments in 2005 will increase by 2.40 times as many as that of 1975. On the other hand, the growth of secondary industries will be low, namely 1.48 times as many. This fact shows tertiary industries will be given much weight in the future. Net product will increase in 2005 by 5.7 times as many as that of 1975 under economic growth rate 6 percent. But owing to the increase of employees, the growth of income will be low.

Land Use Sector:

Because of the gravitation of population towards cities, housing-land will be in short supply by 4.42 $Km^2$ in 2005 under current housing-land-supply program. This implies housing trouble will be serious in the future. The movements of land use are shown in Fig.21.

## 4. Concluding Remarks

In this study, a system dynamics model to forecast future movements of city was formed and conditions of Okayama city up to A.D.2005 were estimated through current political variables. The results show that the drift of population from central and nothern part of the prefecture into Okayama city will advance in the future, and evil influences such as housing problems will arise.

For well-balanced development of Okayama prefecture, employment oppotunity should be increased and settlement of peoples must be strived, through concentrated investment for industry and living bases in central and nothern part of the prefecture.

Now, this model is not necessarily satisfactory, so that it should be reviesd. Fine zoning of the study area, consideration of population movements in classified age-grade and feed-back loop owing to lack of land in population sector and industry sector are the problems for further investigation.

Reference

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[5] Report of the Statistical Research of Establishments, (1978)
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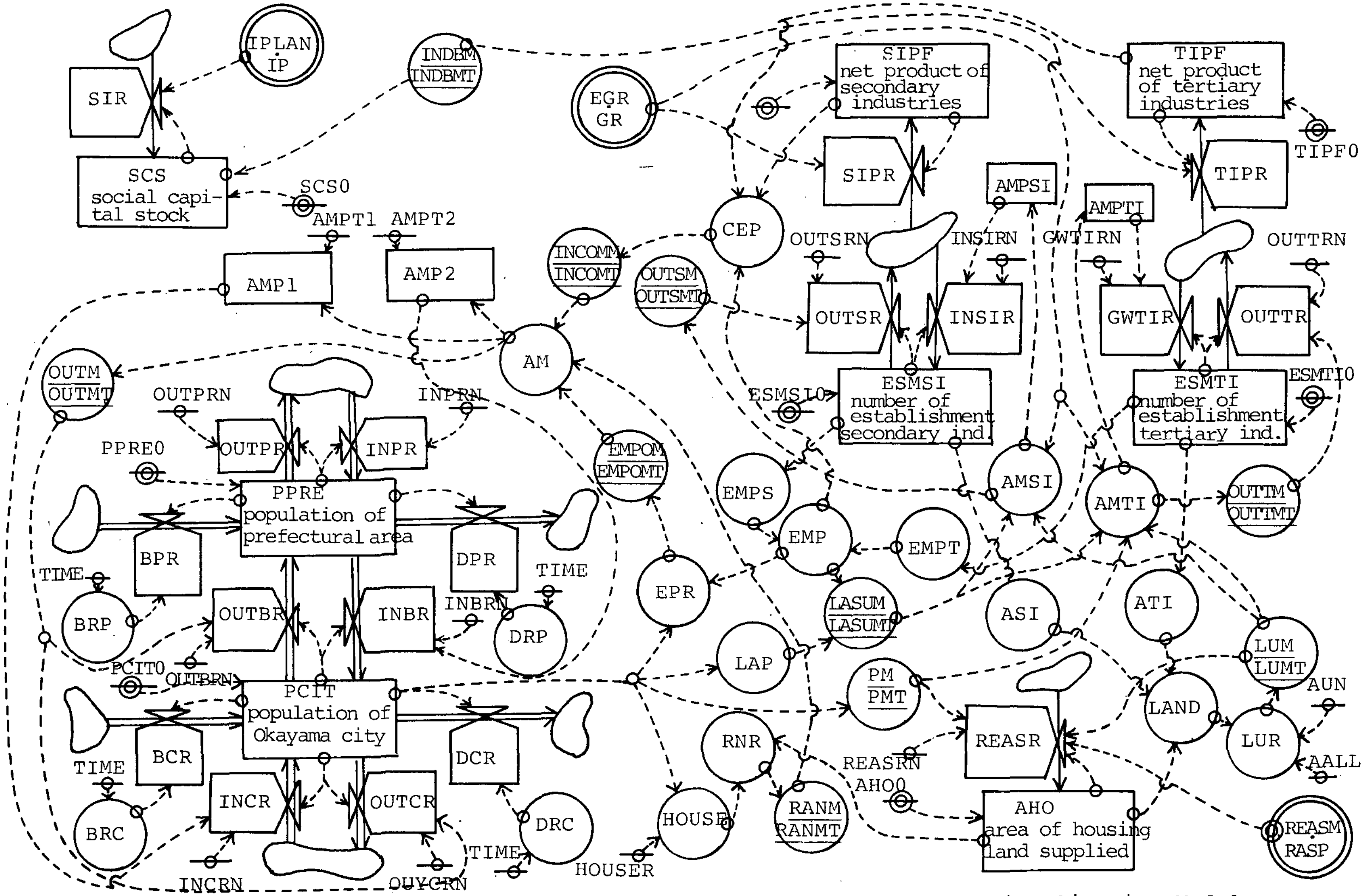
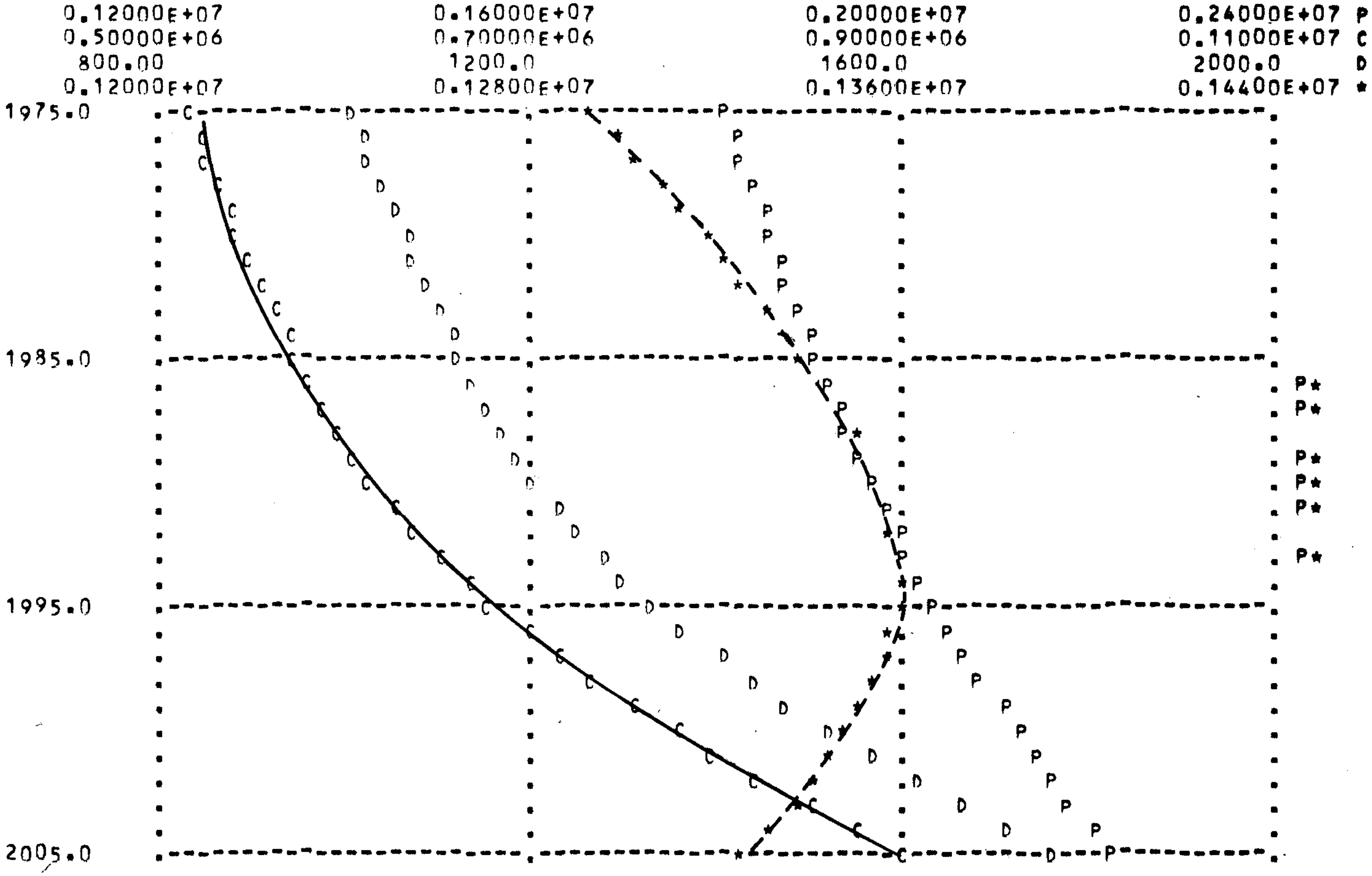
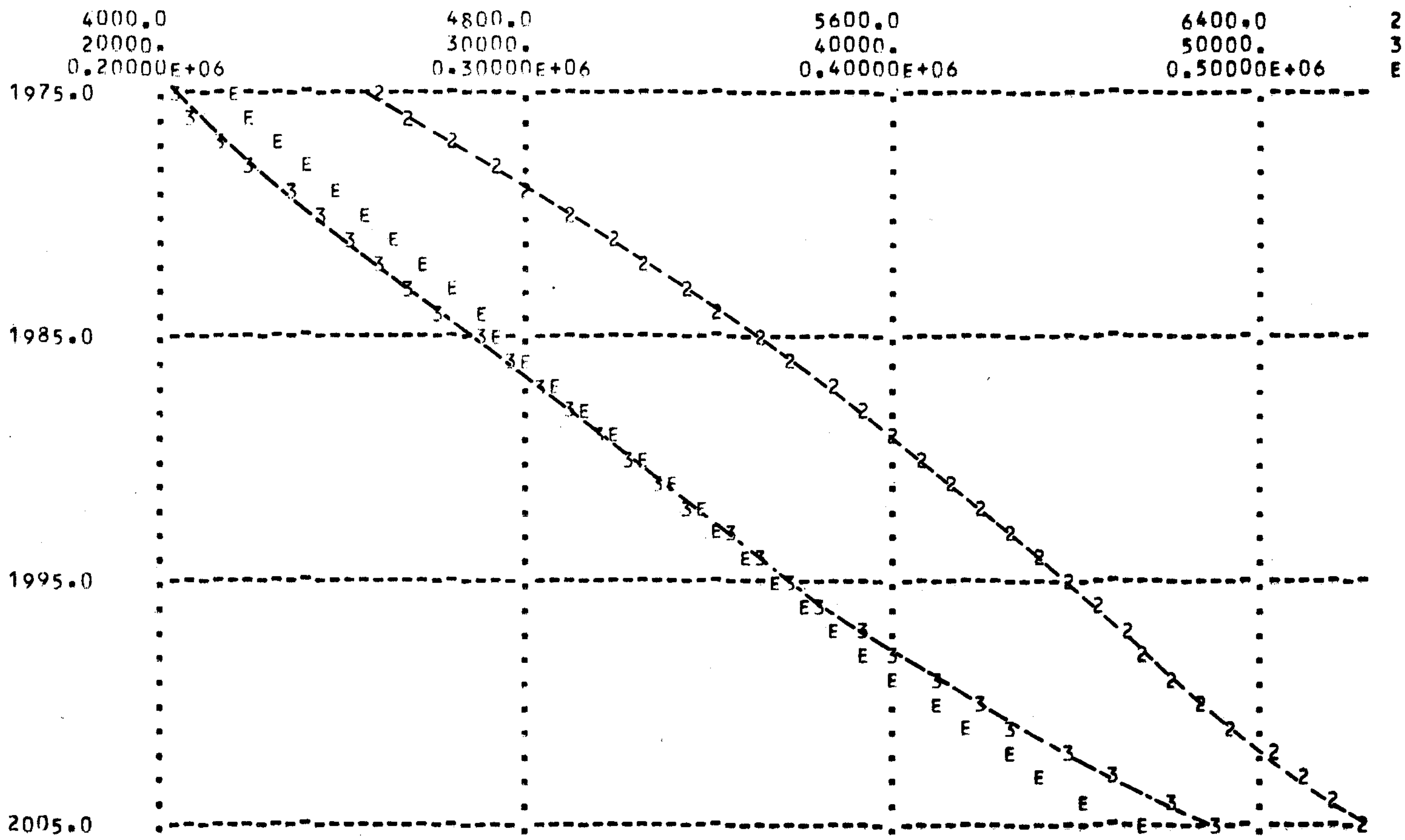



Fig.18 Total Flow Diagram of Okayama City Dinamics Model



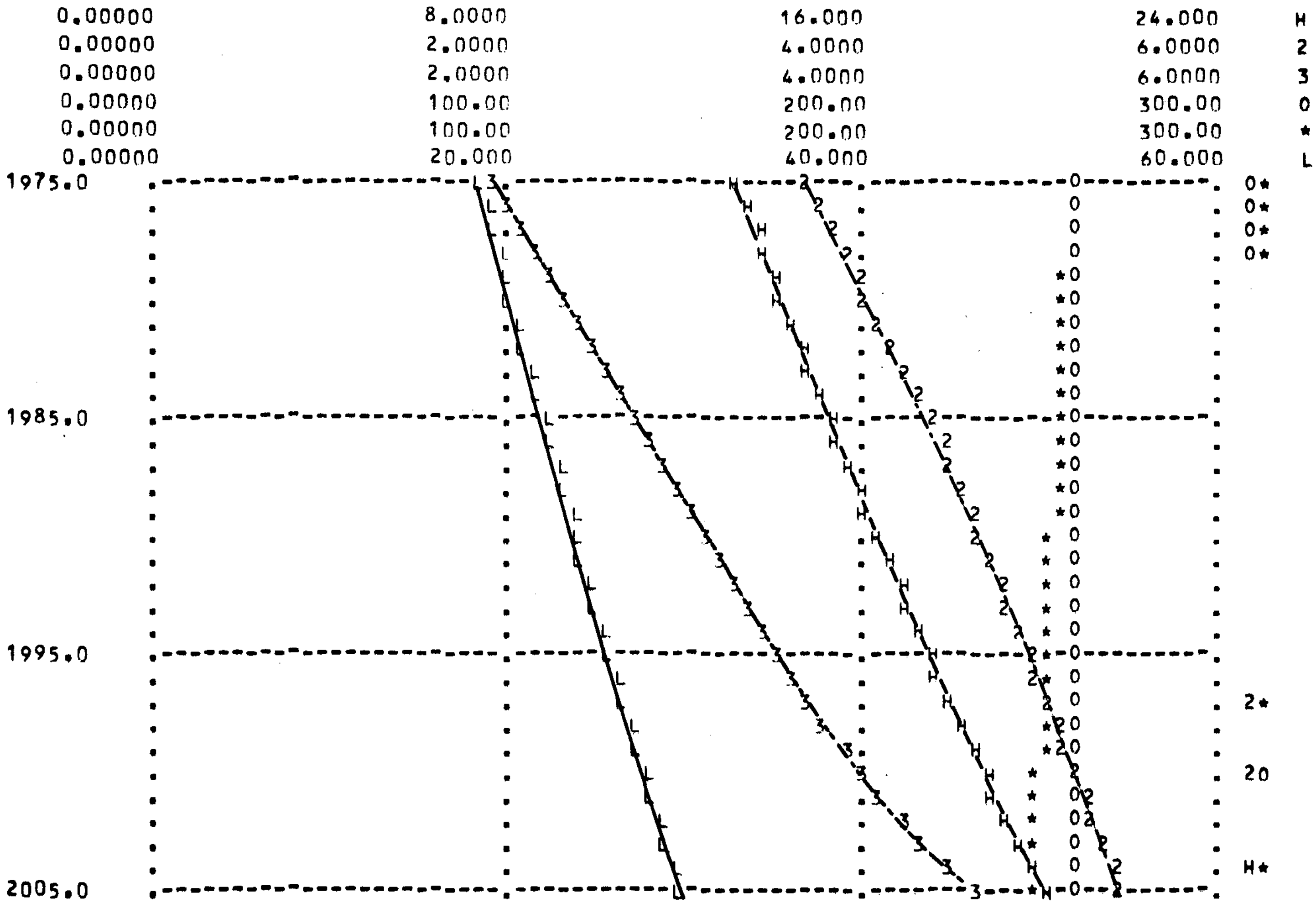

P : population of Okayama prefecture (men)
C : population of Okayama city (men)
D : population density (men/Km$^2$)
* : population of the prefectural area

Fig.19 Movements of Population sector




2 : number of establishments of secondary industries
3 : number of establishments of tertiary industries
E : total number of employees (men)

Fig.20 Movements of Industry Sector




H : area of housing-land ($Km^2$)
2 : area of establishments of secondary industries ($Km^2$)
3 : area of establishments of tertiary industries ($Km^2$)
o : area of available land in 1975 ($Km^2$)
* : area of available land ($Km^2$)
L : total area of land used ($Km^2$)

Fig.21 Movements of Land Use Sector